How to wire Ethernet Cables

ertyu.org/steven_nikkel/ethernetcables.html

How to wire your own ethernet cables and connectors.

What You Need:

Required:

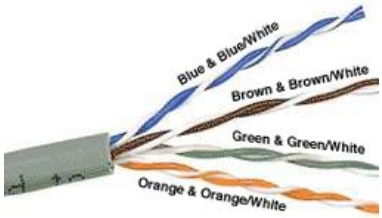
- Ethernet Cable - bulk Category (Cat) 5, 5e, 6, 6a or higher ethernet cable
- Wire Cutters - to cut and strip the ethernet cable if necessary
- **For Patch Cables:**
  - 8P8C Modular Connector Plugs ("RJ45")
  - Modular Connector Crimper ("RJ45")
- **For Fixed Wiring:**
  - 8P8C Modular Connector Jacks ("RJ45")
  - 110 Punch Down Tool

Recommended:

- Wire Stripper
- Cable Tester

About the Cable:

You can find bulk supplies of ethernet cable at many computer stores or most electrical or home centers. You want UTP (Unshielded Twisted Pair) ethernet cable of at least Category 5 (Cat 5). Cat 5 is required for basic 10/100 functionality, you will want Cat 5e for gigabit (1000BaseT) operation and Cat 6 or higher gives you a measure of future proofing. You can also use STP (Shielded Twisted Pair) for extra resistance to external interference but I won't cover shielded connectors. Bulk ethernet cable comes in many types, there are 2 basic categories, solid and braided stranded cable. Stranded ethernet cable tends to work better in patch applications for desktop use. It is more flexible and resilient than solid ethernet cable and easier to work with, but really meant for shorter lengths. Solid ethernet cable is meant for longer runs in a fixed position. Plenum rated ethernet cable must be used whenever the cable travels through an air circulation space. For example, above a false ceiling or below a raised floor. It may be difficult or impossible to tell from the package or labeling what type of ethernet cable it is, so peal out an end and investigate.
Here is what the internals of the ethernet cable look like:



Internal Cable Structure and Color Coding

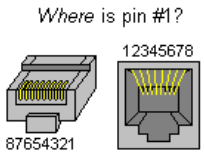
Inside the ethernet cable, there are 8 color coded wires. These wires are twisted into 4 pairs of wires, each pair has a common color theme. One wire in the pair being a solid or primarily solid colored wire and the other being a primarily white wire with a colored stripe (Sometimes ethernet cables won't have any color on the striped wire, the only way to tell which is which is to check which wire it is twisted around). Examples of the naming schemes used are: Orange (alternatively Orange/White) for the solid colored wire and White/Orange for the striped cable. The twists are extremely important. They are there to counteract noise and interference. It is important to wire according to a standard to get proper performance from the ethernet cable. The TIA/EIA-568-A specifies two wiring standards for an 8-position modular connector such as RJ45. The two wiring standards, T568A and T568B vary only in the arrangement of the colored pairs. Tom writes to say "...sources suggest using T568A cabling since T568B is the AT&T standard, but the US Government specifies T568A since it matches USOC cabling for pairs 1 & 2, which allows it to work for 1/2 line phones...". Your choice might be determined by the need to match existing wiring, jacks or personal preference, but you should maintain consistency. I've shown both below for straight through cabling and just T568B for crossover cabling.

About Modular Connector Plugs and Jacks:

The 8P8C modular connectors for Ethernet are often called RJ45 due to their physical resemblance. The plug is an 8-position modular connector that looks like a large phone plug. There are a couple variations available. The primary variation you need to pay attention to is whether the connector is intended for braided or solid wire. For braided/stranded wires, the

connector has sharp pointed contacts that actually pierce the wire. For solid wires, the connector has fingers which cut through the insulation and make contact with the wire by grasping it from both sides. The connector is the weak point in an ethernet cable, choosing the wrong one will often cause grief later. If you just walk into a computer store, it's nearly impossible to tell what type of plug it is. You may be able to determine what type it is by crimping one without a cable. Modular connector jacks come in a variety styles intended for several different mounting options. The choice is one of requirements and preference. Jacks are designed to work only with solid ethernet cable. Most jacks come labeled with color coded wiring diagrams for either T568A, T568B or both. Make sure you end up with the correct one.

Here is a wiring diagram and pin out:



Modular Connector Plug and Jack Pin Out

Ethernet Cable Pin Outs:

There are two basic ethernet cable pin outs. A straight through ethernet cable, which is used to connect to a hub or switch, and a crossover ethernet cable used to operate in a peer-to-peer fashion without a hub/switch. Generally all fixed wiring should be run as straight through. Some ethernet interfaces can cross and un-cross a cable automatically as needed, a handy feature.

Standard, Straight-Through Wiring Diagram(both ends are the same):

RJ45 Pin #	Wire Color (T568A)	Wire Diagram (T568A)	10Base-T Signal 100Base-TX Signal	1000Base-T Signal
1	White/Green		Transmit+	BI_DA+
2	Green		Transmit-	BI_DA-
3	White/Orange		Receive+	BI_DB+
4	Blue		Unused	BI_DC+
5	White/Blue		Unused	BI_DC-
6	Orange		Receive-	BI_DB-
7	White/Brown		Unused	BI_DD+
8	Brown		Unused	BI_DD-

Straight-Through Ethernet Cable Pin Out for T568A

RJ45 Pin #	Wire Color (T568B)	Wire Diagram (T568B)	10Base-T Signal 100Base-TX Signal	1000Base-T Signal
1	White/Orange		Transmit+	BI_DA+
2	Orange		Transmit-	BI_DA-
3	White/Green		Receive+	BI_DB+
4	Blue		Unused	BI_DC+
5	White/Blue		Unused	BI_DC-
6	Green		Receive-	BI_DB-
7	White/Brown		Unused	BI_DD+
8	Brown		Unused	BI_DD-

Straight-Through Ethernet Cable Pin Out for T568B

Crossover Cable Wiring Diagram:

RJ45 Pin # (END 1)	Wire Color	Diagram End #1	RJ45 Pin # (END 2)	Wire Color	Diagram End #2
1	White/Orange		1	White/Green	
2	Orange		2	Green	
3	White/Green		3	White/Orange	
4	Blue		4	White/Brown	
5	White/Blue		5	Brown	
6	Green		6	Orange	
7	White/Brown		7	Blue	
8	Brown		8	White/Blue	

Crossover Ethernet Cable Pin Outs
+Note: The crossover ethernet cable layout is suitable for 1000Base-T operation, all 4 pairs are crossed.

How to wire Ethernet Patch Cables:

1. Strip off about 2 inches of the ethernet cable sheath.
2. Untwist the pairs - don't untwist them beyond what you have exposed, the more untwisted cable you have the worse the problems you can run into.
3. Align the colored wires according to the wiring diagrams above.
4. Trim all the wires to the same length, about 1/2" to 3/4" left exposed from the sheath.
5. Insert the wires into the RJ45 plug - make sure each wire is fully inserted to the front of the RJ45 plug and in the correct order. The sheath of the ethernet cable should extend into the plug by about 1/2" and will be held in place by the crimp.
6. Crimp the RJ45 plug with the crimper tool.
7. Verify the wires ended up the right order and that the wires extend to the front of the RJ45 plug and make good contact with the metal contacts in the RJ45 plug
8. Cut the ethernet cable to length - make sure it is more than long enough for your needs.
9. Repeat the above steps for the second RJ45 plug.

How to wire fixed Ethernet Cables:

1. Run the full length of ethernet cable in place, from endpoint to endpoint, making sure to leave excess.
2. At one end, cut the wire to length leaving enough length to work, but not too much excess.
3. Strip off about 2 inches of the ethernet cable sheath.
4. Align each of the colored wires according to the layout of the jack.
5. Use the punch down tool to insert each wire into the jack.
6. Repeat the above steps for the second RJ45 jack.

If an ethernet cable tester is available, use it to verify the proper connectivity of the cable. That should be it, if your ethernet cable doesn't turn out, look closely at each end and see if you can find the problem. Often a wire ended up in the wrong place or one of the wires is making no contact or poor contact. Also double check the color coding to verify it is correct. If you see a mistake or problem, cut the end off and start again. A ethernet cable tester is invaluable at identifying and highlighting these issues.

When sizing ethernet cables remember that an end to end connection should not extend more than 100m (~328ft). Try to minimize the ethernet cable length, the longer the cable becomes, the more it may affect performance. This is usually noticeable as a gradual decrease in speed and increase in latency.

Notes:

Power over Ethernet (PoE):

Power over Ethernet has been implemented in many variations before IEEE standardized 802.3af. IEEE 802.3af specifies the ability to supply an endpoint device with 48V DC at up 350mA or approximately 16.8W. IEEE 802.3at updates the PoE standard to supply up to 600mA or approximately 28.8W, it is often known as PoE+. The power is delivered using two pairs in the ethernet cable. The device must be capable of receiving power on either the data pairs [Mode A] (often called phantom power) or the unused pairs in 100Base-TX [Mode B]. IEEE 802.3bt further updates the PoE standard to use all four

pairs of the cable to deliver up to 90W of power. PoE can be used with any ethernet configuration, including 10Base-T, 100Base-TX or 1000Base-T. Power is only supplied when a valid PoE endpoint is detected by using a low voltage probe to look for the PoE signature on the endpoint. PoE power is typically supplied in one of two ways, either the host ethernet switch provides the power, or a "midspan" device is plugged in between the switch and endpoints and supplies the power. No special cabling is required.

RJ45 Pin #	Wire Color (T568A)	Wire Diagram (T568A)	10Base-T Signal 100Base-TX Signal	PoE
1	White/Green		Transmit+	Mode A +
2	Green		Transmit-	Mode A +
3	White/Orange		Receive+	Mode A -
4	Blue		Unused	Mode B +
5	White/Blue		Unused	Mode B +
6	Orange		Receive-	Mode A -
7	White/Brown		Unused	Mode B -
8	Brown		Unused	Mode B -

Power over Ethernet Power Delivery

Protocol Details:

Protocol	Standard	Symbol Encoding	Symbol Rate (Mbaud)	Data Encoding	Data Bits per Symbol	Pairs per Channel	Pairs Used	Nyquist Frequency Bandwidth (MHz)	Minimum Cable Category
10Base-T	IEEE 802.3i	Manchester	10	None	1	1	2	10	3
100Base-TX	IEEE 802.3u	MLT-3	125	4B5B	4/5	1	2	62.5	5
1000Base-T	IEEE 802.3ab	4D-PAM5	125	None	2	4	4	62.5	5e (5)[1]
2.5GBase-T	IEEE 802.3bz	DSQ128 (2D-PAM16)	200	LDPC(1723,2048), 64B/65B, CRC8	3.125	4	4	100	5e[2]
5GBase-T	IEEE 802.3bz	DSQ128 (2D-PAM16)	400	LDPC(1723,2048), 64B/65B, CRC8	3.125	4	4	200	6 (5e)[2]
10GBase-T	IEEE 802.3an	DSQ128 (2D-PAM16)	800	LDPC(1723,2048), 64B/65B, CRC8	3.125	4	4	400	6a (6)[3]
25GBase-T	IEEE 802.3bq	DSQ128 (2D-PAM16)	2000	LDPC(1723,2048), 64B/65B, CRC8	3.125	4	4	1000	8[4]
40GBase-T	IEEE 802.3bq	DSQ128 (2D-PAM16)	3200	LDPC(1723,2048), 64B/65B, CRC8	3.125	4	4	1600	8[4]

Data Rate = Symbol Rate x Data Bits per Symbol x Pairs per Channel

The combination of the Symbol Encoding and Data Encoding determines how many Data Bits per Symbol there are.

1. Designed to work on most Cat 5 ethernet cable, Cat 5e specifications ensure 1000Base-T operation.
2. Although designed for Cat 5e/6, not all cabling will be usable at the full range, especially for 5GBase-T on Cat 5e.
3. Reduced range when used with Cat 6 (55m), Cat 6a supports the full 100m range. Some Cat 5e may support operation at reduced distance.
4. 30m range.

Cable Category Details:

Cable Category	Rated Nyquist Frequency Bandwidth (MHz)	Common Uses
1	None	Telephone Wiring
2	1	Telephone Wiring
3	16	Telephone Wiring, 10Base-T
4	20	Token-Ring, 10Base-T
5	100	100Base-TX, 10Base-T
5e	100	1000Base-T, 100Base-TX
6	250	1000Base-T, 100Base-TX
6a	500	10GBase-T
7[1]	600	>10GBase-T
7a[1]	1000	>10GBase-T
8	2000	25GBase-T, 40GBase-T

Increasing category levels are backward compatible.
Manufacturers will often test and certify their ethernet cable well beyond the standards.
1. Category 7/7a specification wiring does not use RJ45 connectors.